SECRET

CHAL - 0984

16 May 1960

MEMORANDUM FOR : Deputy Director (Plans)

SUBJECT : Modified U-2 for Navy Aircraft Carrier Operation

1. Latest LAC document on this subject, 14 August 1957, is attached. The modifications called for probably should be reviewed with Navy personnel who have up to date information on carriers.

2. Two kinds of changes are given:

(a) "Must" changes:

(1) stronger main and tail gear
(2) arresting hook
(3) fuel dump mechanism

(b) Extra safety and convenience changes:

(1) retractable pogos
(2) JATO
(3) detachable wing tips
(4) landing gear built for high sinking speed.

3. The minimum "must" changes add about 230 lbs. and probably would take 3 - 5 months to modify the first aircraft. The extra safety and convenience changes could add 500 lbs. depending on extent and involve some small loss of fuel volume.

4. Carrier qualifications may be troublesome and time consuming. It would mean extensive training of either present pilots in carrier operations or carrier qualified pilots in U-2 handling.

5. A quick glance at the map indicates operations from the North Sea, Mediterranean, Pacific, and Indian oceans could yield coverage of all but the upper central third of denied area. I am very rusty on Navy carrier operations in the Arctic but recall it was rather hazardous.

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MODIFIED U-2

The U-2 may be modified for carrier operations as described herein. Performance and landing characteristics are summarized.

Appendix of detachable wings, large sink rates and 1000# bay loads has been added.

Revised 8-14-57

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DESCRIPTION

AIRPLANE

The U-2 is a single place, jet propelled aircraft designed for extremely high altitude, long range operation. The aircraft is powered by a single J57-P-31 non-afterburning engine, which employs an axial flow, twin spool compressor, and a split three stage turbine. The basic configuration has a pressurized equipment bay for various equipment which can be installed for special missions.

BASIC DIMENSIONS

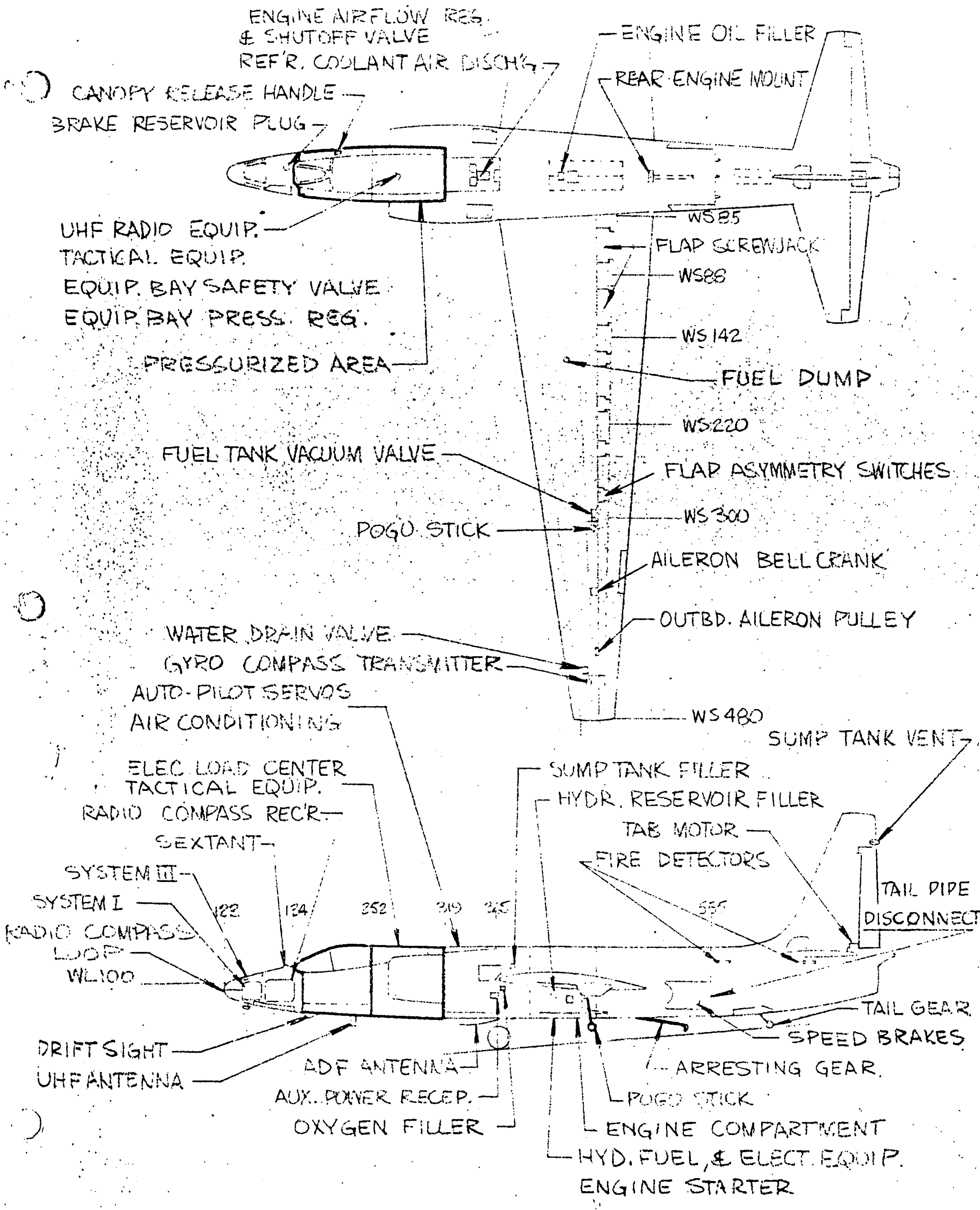
Wing area	600 sq. ft.
Wing Span	80 ft.
Aspect Ratio	10.67
Wing Average Thickness	7.8%
Fuselage Length	49.7 Ft.

GROSS WEIGHTS

CONDITION	FUEL LOADING	GROSS WEIGHT
Full main & empty aux. tanks	1035 Gal.	17,817 Lbs.
Full main & full aux. tanks	1335 Gal.	19,767 Lbs.
Nominal landing weight	200 Gal.	12,390 Lbs.

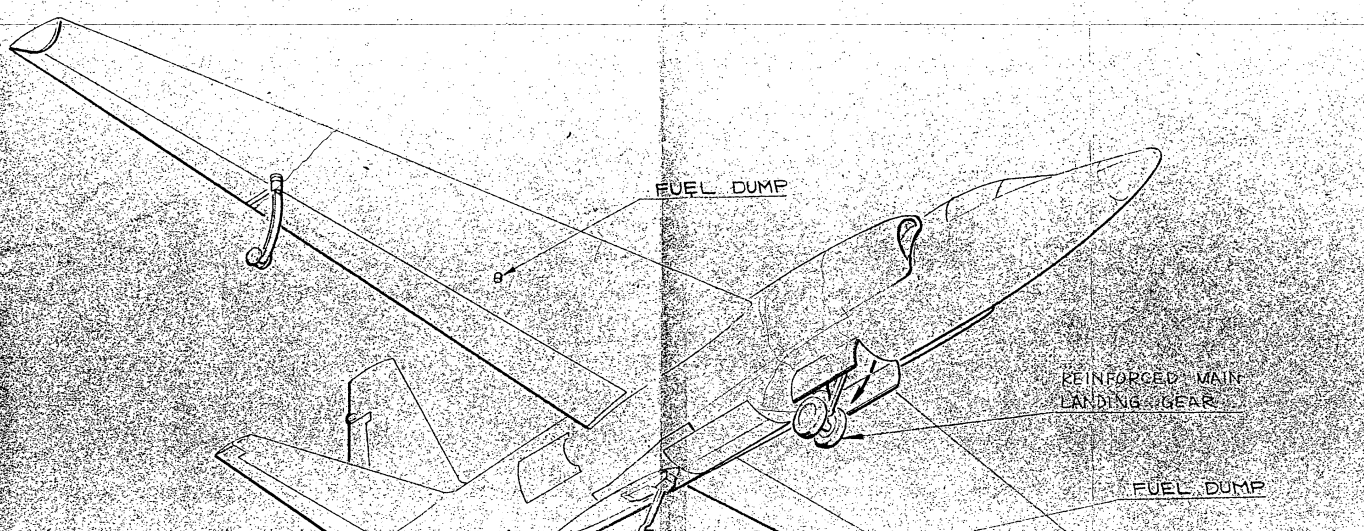
CARRIER ADAPTATION

The U-2 with the minimum required modifications for carrier operation is shown in figures 1 and 2. The minimum modifications would consist of:



BASIC DIMENSIONS & GENERAL INFORMATION

 GURE 1



MODEL U-2 AIRPLANE
WITH
MINIMUM CARRIER PROVISIONS

1. Main gear and attaching structure redesigned for load factor of 3.6.
2. Tail gear and attaching structure redesigned for higher load factor. Incorporate a cable deflector to deflect arresting gear cables below tail wheels.
3. Install an arresting hook and associated structure. Provide for a fairing to streamline the hook installation. Fairing to be jettisoned by hook when it is lowered.
4. Provide a fuel dump system to permit dumping fuel before landing in the event of an aborted mission.

The weight increase due to the modifications listed above would be 227 lbs.

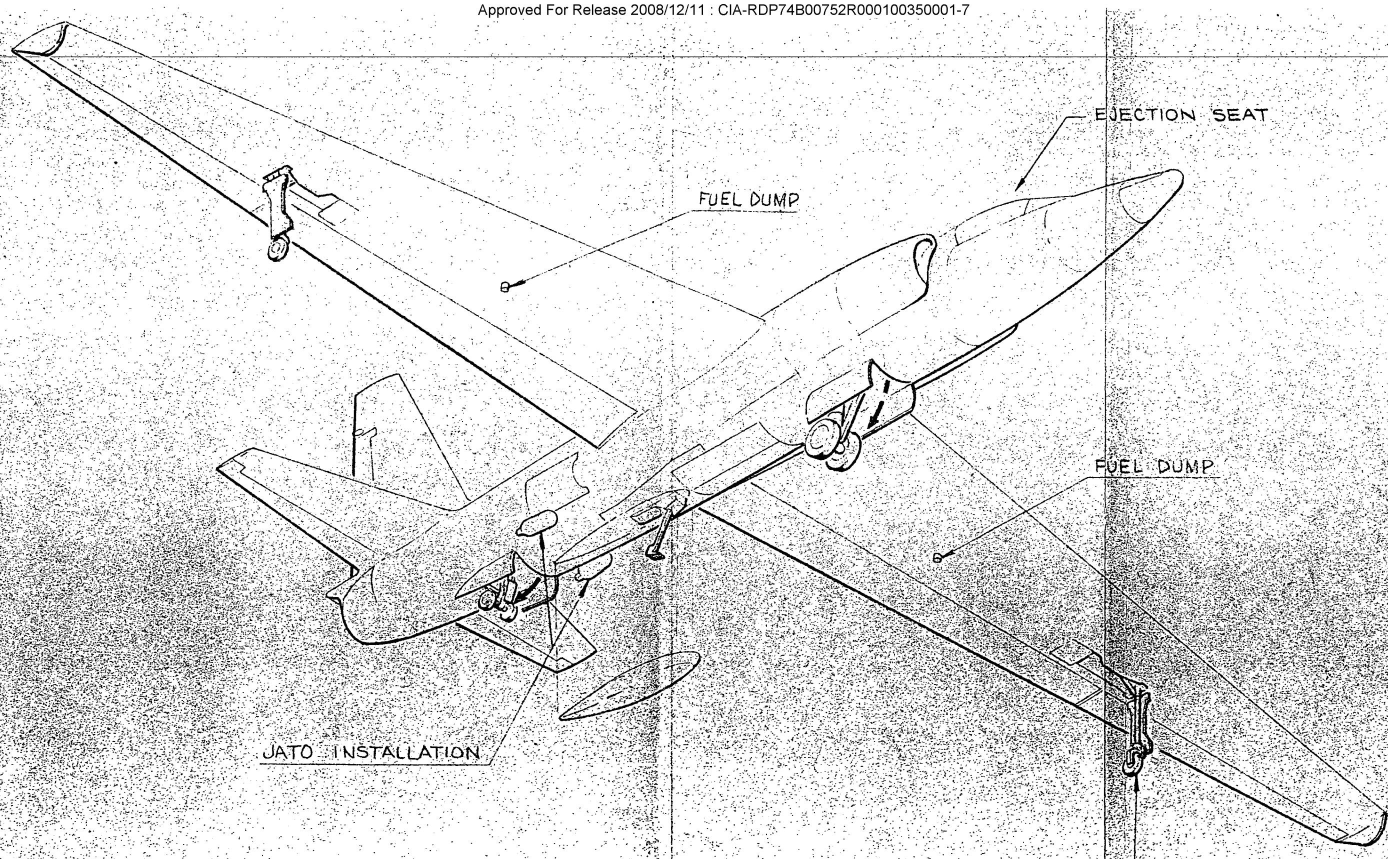
The design landing weight of the modified U-2 is based on the Zero Fuel Weight including the original 450 lbs. of equipment plus the estimated weight of the modifications and 200 gal. of fuel. As stated above provision is made for fuel dumping to allow landings under all conditions.

Wt. Basic Airplane	10,413 lb.✓
Modifications for carrier operations	227
Wt. Basic Modified Airplane	10,640 lb.
Equipment	450
Zero Fuel Wt.	11,090 lb.
200 gal. fuel (200 x 6.5)	1,300
Nominal Landing Wt.	12,390 lb.

Further modifications beyond the minimum are possible and may be desirable for some carrier operations. These modifications would consist of:

1. Jettison seat for pilot escape thru the canopy.
2. Retractable pogos for use in landing as well as take-off.
3. JATO installation for very short take-off ground runs.

Figure 3 illustrates the U-2 with all of the discussed modifications incorporated.



MODEL U-2 AIRPLANE
WITH
CARRIER PROVISIONS

PERFORMANCE

Take off ground roll distances of the modified U-2 are summarized in the table below. These distances correspond to the gross weight of 19,767 lbs. which is with full main and auxilliary tanks.

WIND KNOTS	JATO BOOST LBS.	GROUND ROLL FT.
0	0	1030
30	0	514
30	2000	403

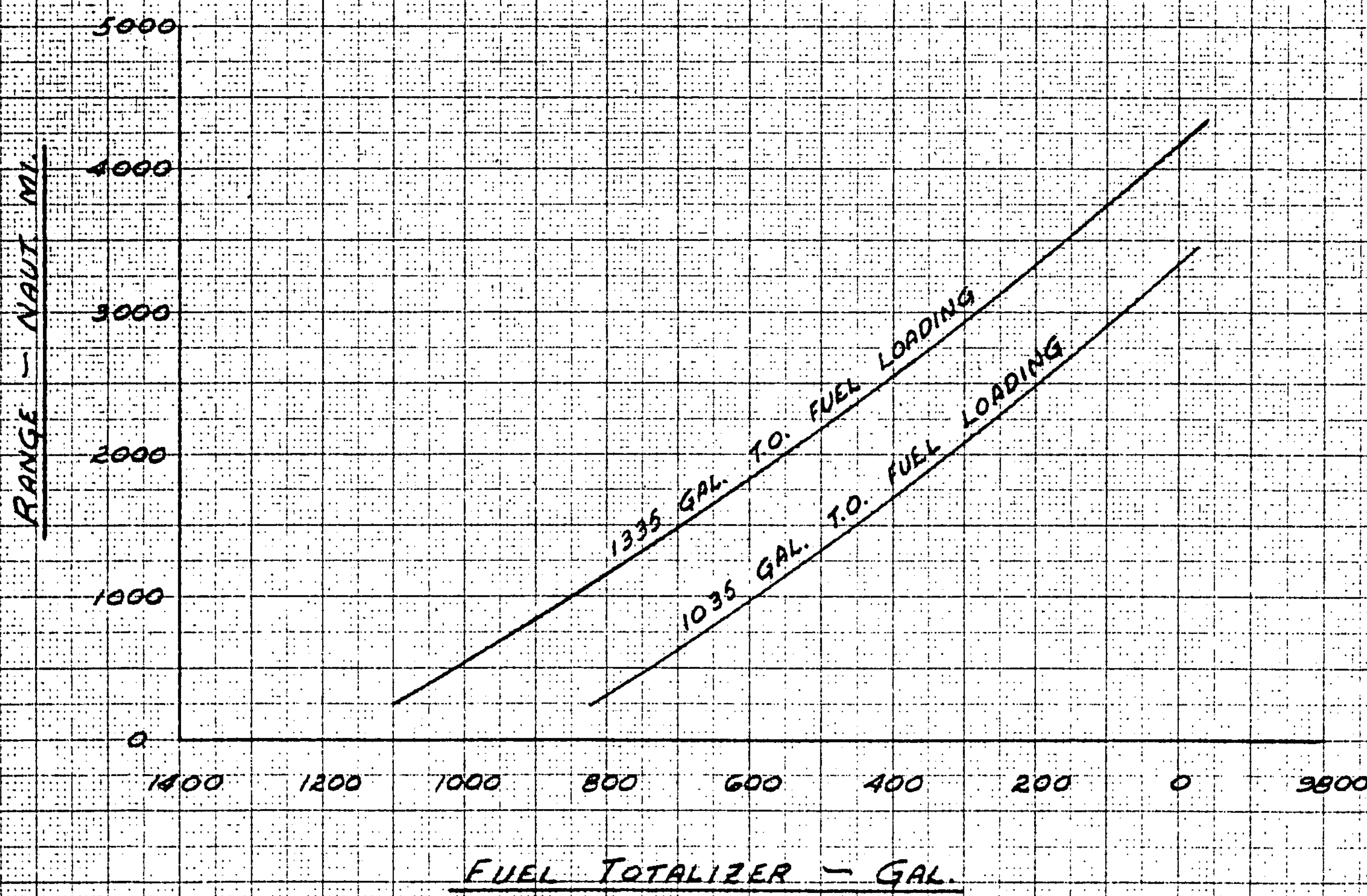
The use of two standard 1000 lb. Jato units will cause the U-2 to be climbed very steeply on takeoff because normal Jato burning time is approximately double the U-2 time required to break ground. Special bottles should be tailored to the U-2 rapid acceleration.

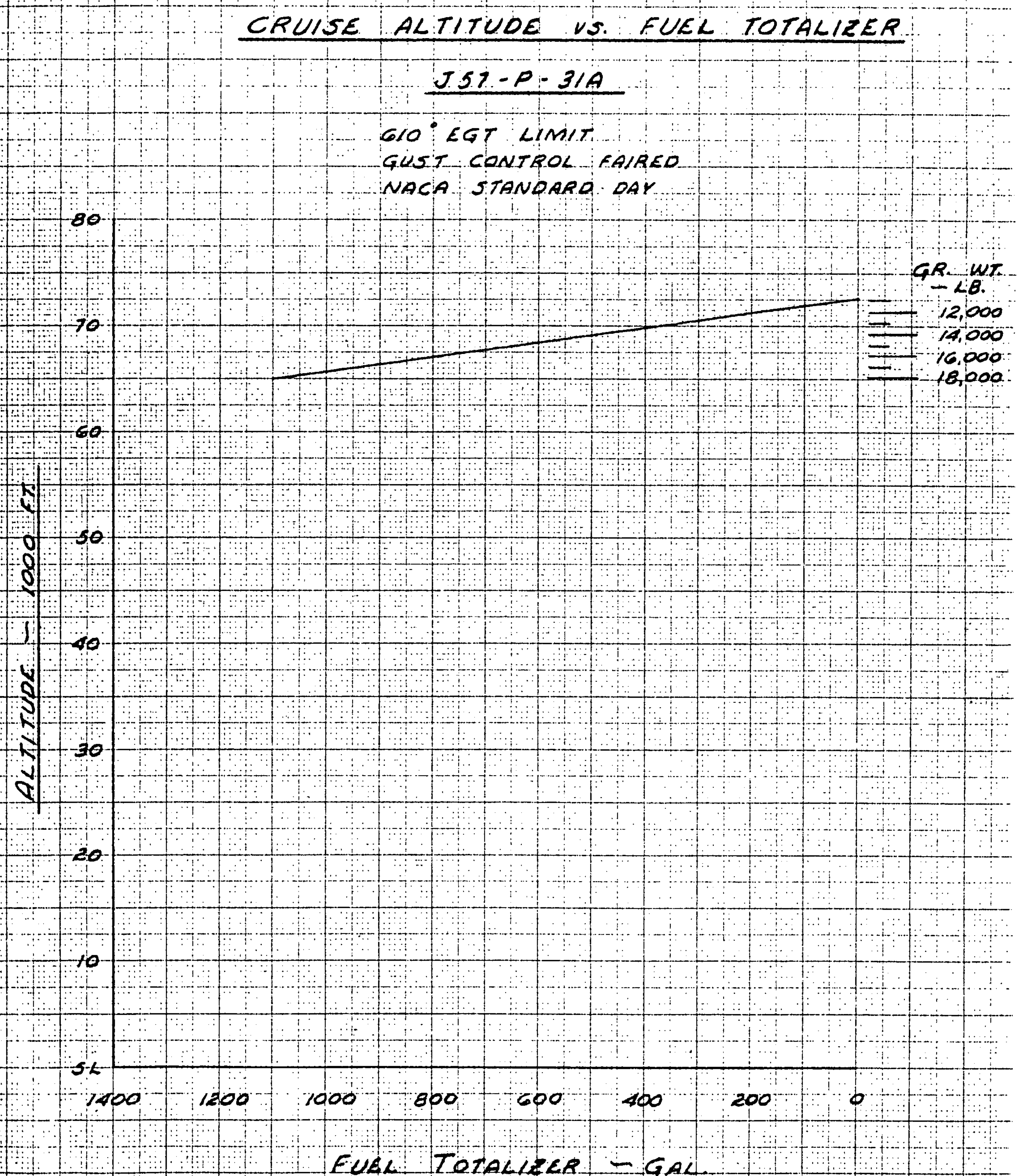
The cruise and altitude performance of the modified U-2 will be as shown in following figures. Performance data shown herein is based on flight test.

CRUISE RANGE VS. FUEL TOTALIZER

J57-P-31A

610° EGT LIMIT
GUST CONTROL FAIRED
NACA STD DAY
ZERO WIND





FORM 527B A

FIGURE 5

LANDING CHARACTERISTICS

THRESHOLD SPEEDS

A curve of threshold speeds for landing is shown in Figure 6 . These speeds are recommended for all wing flap settings. With 15° - 25° of wing flaps, the speeds provide a comfortable stall speed margin of 115% - 118%. For an emergency landing with wing flaps faired, where it is desirable to have a slow but safe threshold speed, the stall margin is 110%.

Airplane stall speeds for various amounts of fuel on board are also shown in Figure 6 . The speeds are shown for 0°, 15°, and 25° of wing flaps. Note that the reduction in stall speed is only about two knots from 15° to 25° flaps. Therefore, a flap setting of 15° - 25° can be selected for landing with little change in touchdown speed. Stall strips are incorporated on inboard L.E. to provide stall warning approximately 3 knots above stall.

In calculations for landing gear and arresting hook loads a combined wind and carrier velocity of 30 knots is assumed. Thus, the effective landing speed for structural design of the aircraft and arresting gear is 50 knots.

STALL SPEEDS

GEAR DOWN
FUEL DENSITY = 6.5 LB/GAL

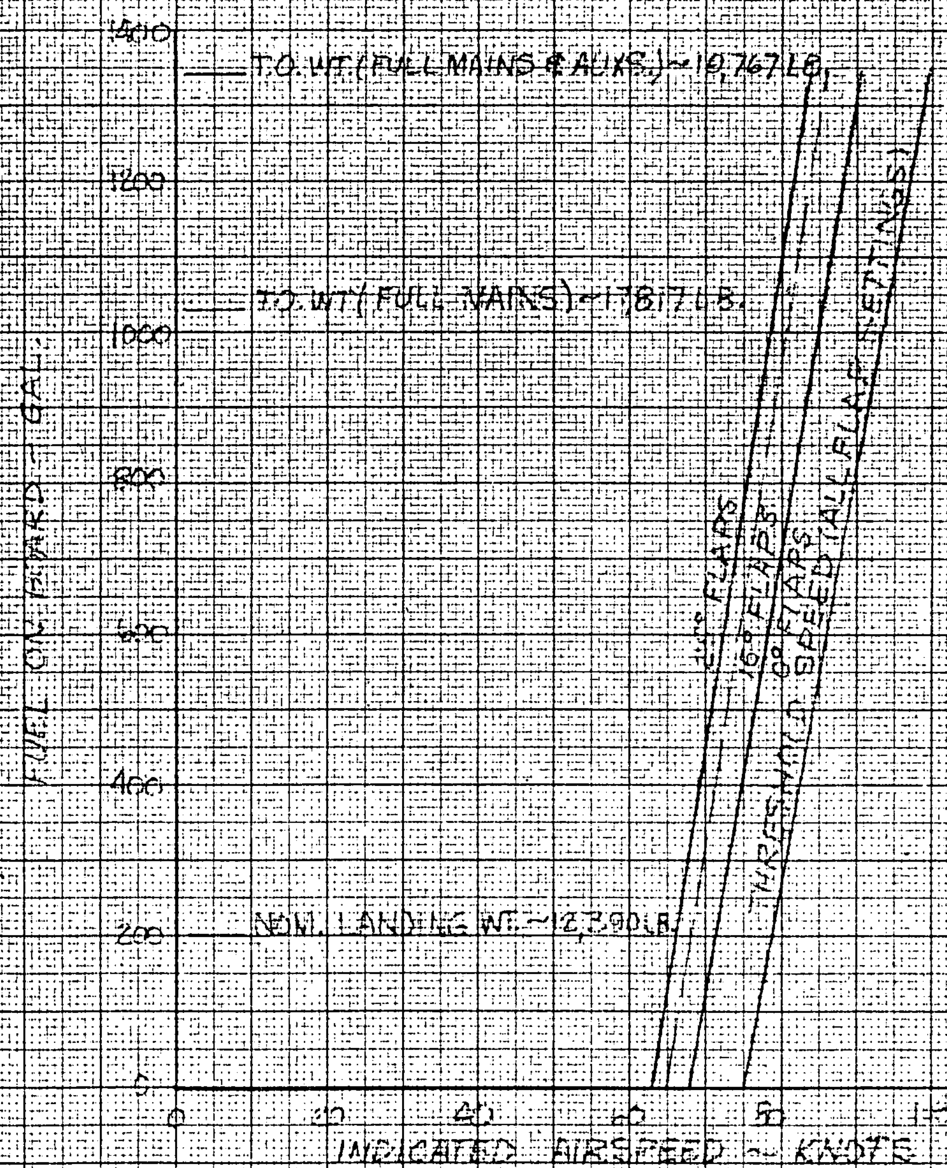


FIGURE 6

DESIGN SINKING SPEED

The main landing gear, the tail landing gear and the fuselage attachment structure shall be modified and redesigned to sustain a design sinking speed of 10 fps. This will result in a main gear design load factor of 3.6.

The design sinking speed could be increased to as much as 15 fps, but this would require an increased strut stroke so as to avoid excessive main gear load factors. This increased strut stroke would require a mechanism on the gear to compress the strut when raising it into the wheel well.

This higher sinking speed will not be considered in this proposal but calculation indicates that a stroke of 15 inches would result in a load factor of 3.5 for the 15 fps. sinking speed.

MAIN GEAR LOAD FACTOR

$$n_{GEAR} = \frac{1}{\lambda}\left[\frac{.0155\ V_v^2}{\delta} + 0.33\right] \quad \triangle 1$$

where λ = assumed strut and tire efficiency

δ = total strut deflection

V_v = design sinking speed for ultimate load

So as to fit the redesigned main gear into the existing wheel well, the total strut deflection will remain unchanged. The appropriate values will then be:

$\triangle 1$ Includes the effect of 2/3 W wing lift per 3.5.1.1.4 of MIL-A-8629.

$\lambda = 0.90$ ⚠1

$\delta = 6.5$ in.

$V_V = 10$ fps

$$n_{GEAR} = \frac{1}{0.90}\left[\frac{1.55}{0.54} + 0.33\right] = 3.56$$

$n_{GEAR} = 3.6$ for design

ARRESTING HOOK LOADS

The arresting hook loads used in this proposal are based on the use of the MK VII Arresting Engine with a runout of 186 ft. and a design landing speed of 50 knots. The use of carriers with longer runouts of 225 ft. would produce lower load factors.

The loads for the design of the arresting hook, its attachment to the fuselage and the fuselage itself, are summarized below for various landing speeds.

$$P_D = \left[\frac{3.18\ V_L^{1.96}}{W} + \frac{0.169\ V_L^{2.12}}{R^{1.32}}\right] W \qquad \text{(MK VII)}$$

Where V_L = design landing speed in knots

W = design landing weight (12,390 lbs.)

R = runout distance (186 ft. for MK VII)

V_E	P_D ⚠2	n_x ⚠2	
50 knots	22,800 lbs.	1.84	(Design value)
60	33,000	2.66	
70	45,100	3.65	
80	60,000	4.84	

⚠1 Metering pin in orifice; tire energy absorption negligible.

⚠2 Ultimate Loads

MODIFICATIONS REQUIRED

LANDING GEAR MODIFICATIONS

The new design criteria for the landing gear is tabulated on the following pages.

The main and tail landing gear will require substantial structural beef-up to carry the increased loads. This will consist of redesigning the present structure so as to provide increased cross-sectional area and bending stiffness. However, the present geometry may be maintained.

New tires will be required but the present brakes will be maintained since carrier operation does not increase the braking requirements.

The following table is a comparison between the conditions which were used originally to design the landing gear and its attachment to the fuselage and the modified conditions for the conversion of the aircraft to carrier operations. The only ones which were modified are those which cannot be directly controlled; i.e. conditions involving the sinking speed of the aircraft on a moving deck. Conditions which are in the realm of control, such as taxi, remain unchanged.

CONDITION	LOADING	U-2	Mod. U-2
Drift Landing	Sinking Speed (fps) Vertical Load Side Load Main Side Load Tail	5 Same for both " " " " " "	10
Spin Up & Spring Back	Sinking Speed (fps) Landing Speed (knots) Vertical Load Drag Load	5 77 Same for both " " "	10 50
Static		Same for both ⚠1	
Braked Roll		Same for both ⚠1	
Pivoting		Same for both ⚠1	
Taxi		Same for both ⚠1	
Grnd Run-Up		Same for both ⚠1	

FUSELAGE MODIFICATIONS

The fuselage will require only minimum modification since the loads due to landing are less severe than the flight gust loads which design the forebody, center section and aft body. A comparison of the ultimate vertical gear load factor of 3.6 based on a 10 fps sinking speed with the ultimate gust load factor of 6.0 verifies this.

⚠1 Some minor changes will occur due to new tires.

However, some modification is required to react the increased gear loads into the existing fuselage shell and to attach the arresting gear and associated equipment onto the exterior of the aircraft. Reference to the proposal layout on Figs. 7 and 8 will show the area of modification and its approximate character.

Essentially, the F. Sta. 365 and 342 Bulkheads will be strengthened to carry the increased main landing gear loads as will the bulkheads that react the tail gear.

Also, the keelson carrying the tail gear loads will be extended and strengthened. The arresting hook and associated gear will be attached to the lower longeron through external angles and a doubler.

A tail wheel cable deflector will also be added.

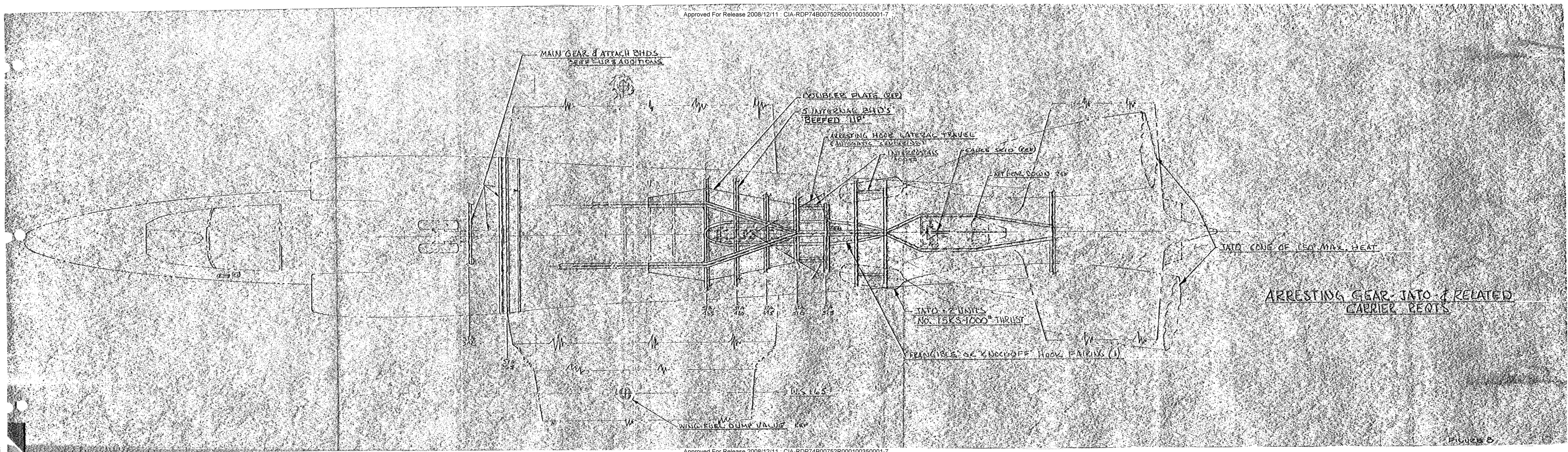
WING MODIFICATIONS

Provision for in-flight fuel dumping will be made in the lower surface of each wing at approximately W. Sta. 165 through the mechanism illustrated in the proposal layout, Fig. 7 .

WEIGHT INCREASE DUE TO MODIFICATIONS

Tabulated below is a break down of the weight increases resulting from the modifications described on the previous pages. They represent estimates based on design studies of the new configuration.

ITEM	WEIGHT INCREASE
Main Gear	70 Lbs.
Tail Gear	20
Fuselage Attach. of Main Gear	25
Fuselage Attach. of Tail Gear	10
Arresting Hook & Related Structure	85
Cockpit Provisions & Wiring	5
Tail Wheel Cable Skid	2
Wing Fuel Dump Provisions	10
	227 Lbs.



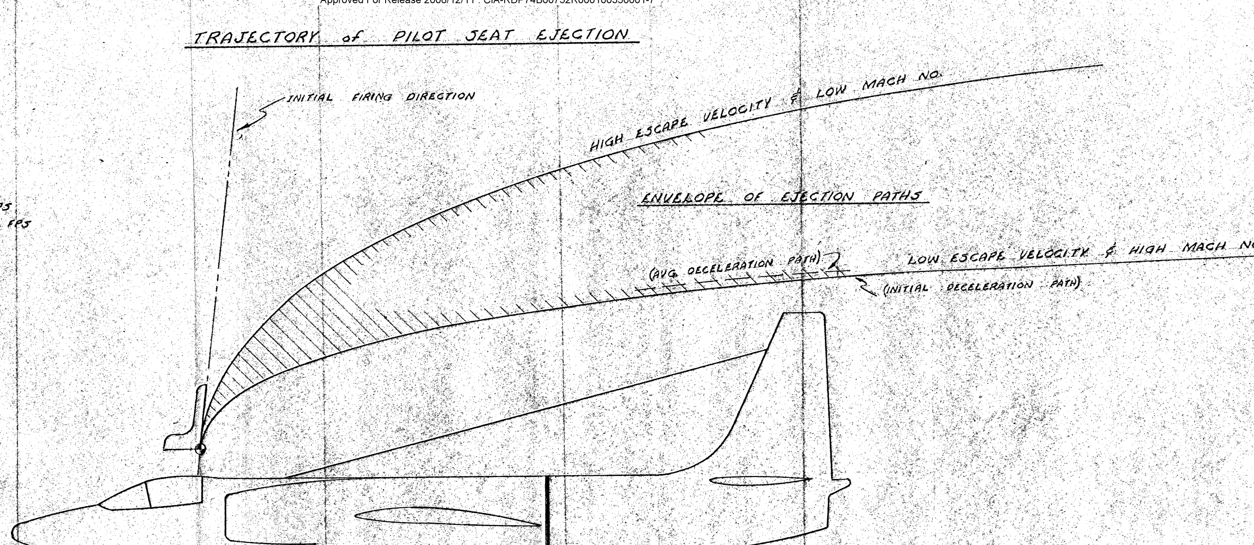
ARRESTING GEAR - JATO & RELATED CARRIER REQTS

FIGURE 8

TRAJECTORY of PILOT SEAT EJECTION

PARAMETERS

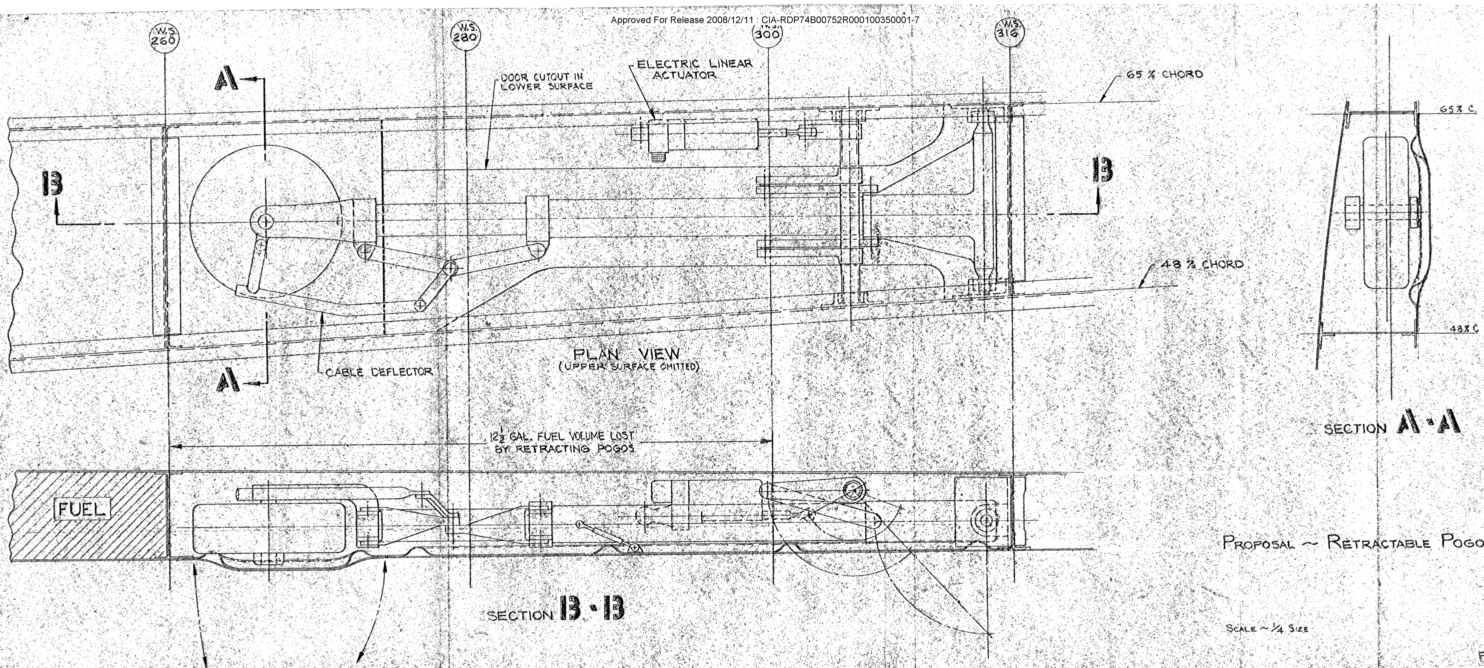
LEVEL FLIGHT
$V\sigma^{1/2}$ = 260 KNOTS (INDICATED)
HIGH MACH NO. = 0.95
LOW MACH NO. < 0.4
350 LB. SEAT - MAN
HIGH ESCAPE VELOCITY = 41 FPS
LOW " " = 27.5 FPS



LOCKHEED U-2 & M1A1 SEAT CATAPULT

SCALE : 1" = 4'

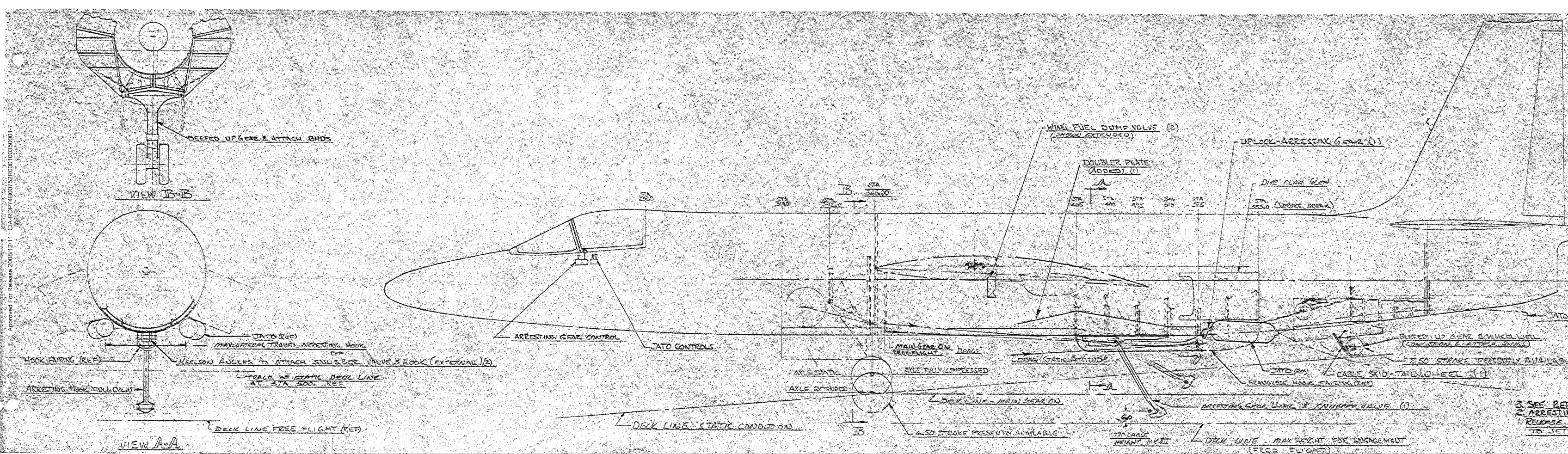
FIGURE 10



PROPOSAL ~ RETRACTABLE POGOS

SCALE ~ ¼ SIZE

FIGURE 11



ARRESTING GEAR - JATO & RELATED
CARRIER REQTS

3. SEE REPORT FOR WEIGHT & PERFORMANCE DATA
2. ARRESTING GEAR RETRACTIBLE BY HYD. SYSTEM PRESSURE
1. RELEASE OF "UPLOCK-ARRESTING GEAR" ALLOWS HOOK TO JETTISON FAIRING.

FIGURE 7

MODIFICATIONS POSSIBLE

JETTISON SEAT

A Jettison Seat for the U-2 would consist of an adaptation of the seat presently used in the T2V. This seat uses a side mounted ejector and file drawer type rails in order to provide maximum pilot clearance during the ejection operation as shown in figure 9 .

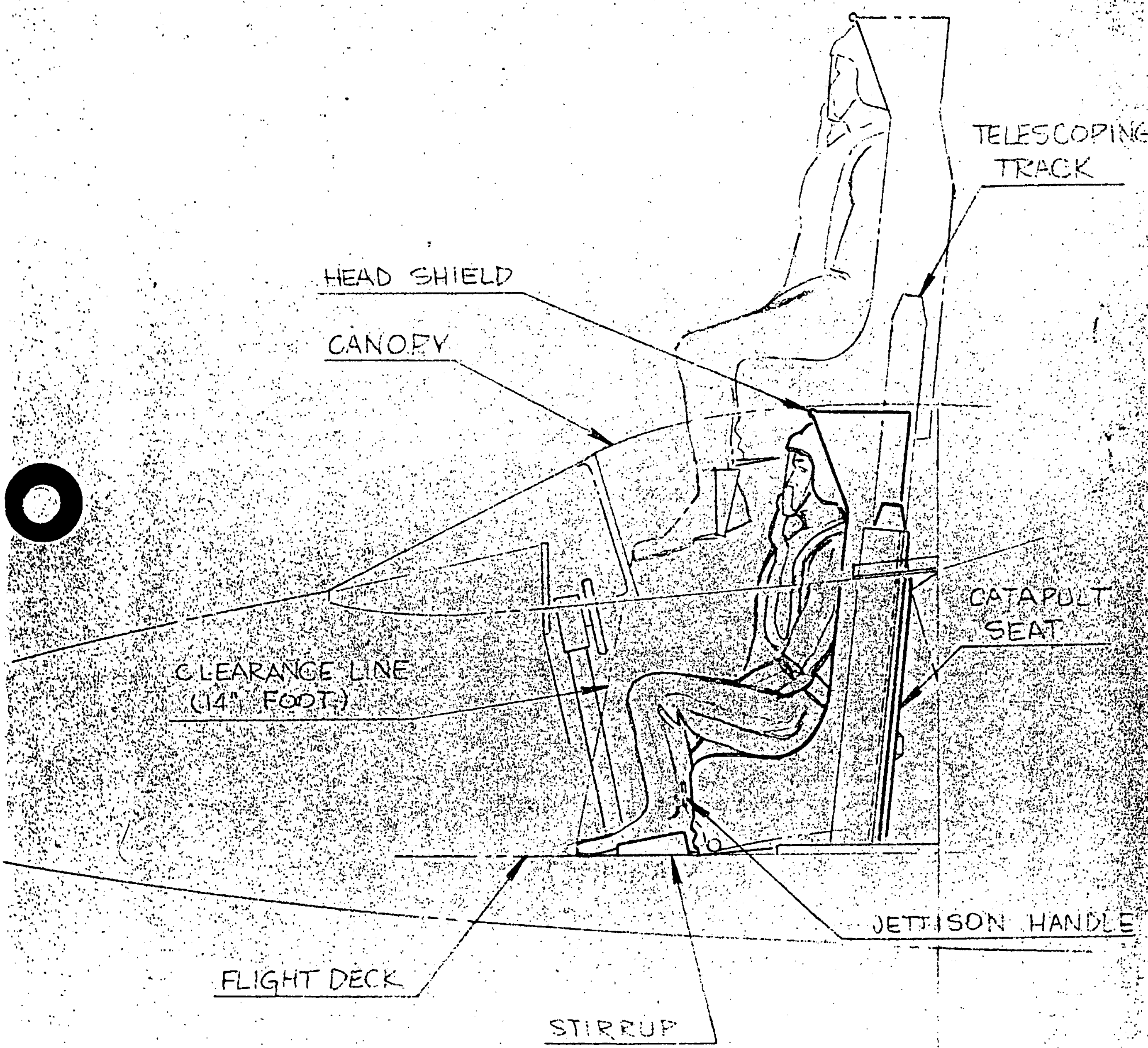
The trajectory of pilot ejection is shown in figure 10. Note that the actual free ejection velocity with the M1A1 catapult of 55 fps has been derated to account for friction and unlocking forces.

The jettison seat installation will cost 80 lbs.

RETRACTABLE POGOS

If pogos are desired for landing as well as take-off they could be made retractable. Such an installation is shown in figure 11. Note that under these conditions an oleo strut would be better than the spring leaf type now used. A cable deflector must be provided as on the tail wheel.

The retractable Pogos would hinge between the beams at 45% and 65% chord. Features of the unit will be a cable deflector on a larger wheel and an oleo shock strut. This installation will involve the loss of a total of 25 gal. of fuel and an estimated net weight decrease of 100 lbs.


TELESCOPING TRACK
HEAD SHIELD
CANOPY
CATAPULT SEAT
CLEARANCE LINE (14" FOOT)
JETTISON HANDLE
FLIGHT DECK
STIRRUP

The preceeding Pogo changes will cost an estimated 40 miles of range.

JATO INSTALLATION

The installation of JATO units may be desirable altho the present take-off ground run is very short. A comparison of take-off performance with and without JATO units is illustrated in the following table.

JATO PERFORMANCE
GROSS WT. 19767 lbs.
30 KNOT HEADWIND

JATO BOOST LBS.	GROUND ROLL FT.
0	514
2000	403
4000	356

This indicates that two 15KS-1000 JATO units may be desirable. The use of more than two JATO units do not appear necessary.

The location and jet conditions for two JATO units is shown on figures 7 and 8 .

14 gal

DETACHABLE WINGS

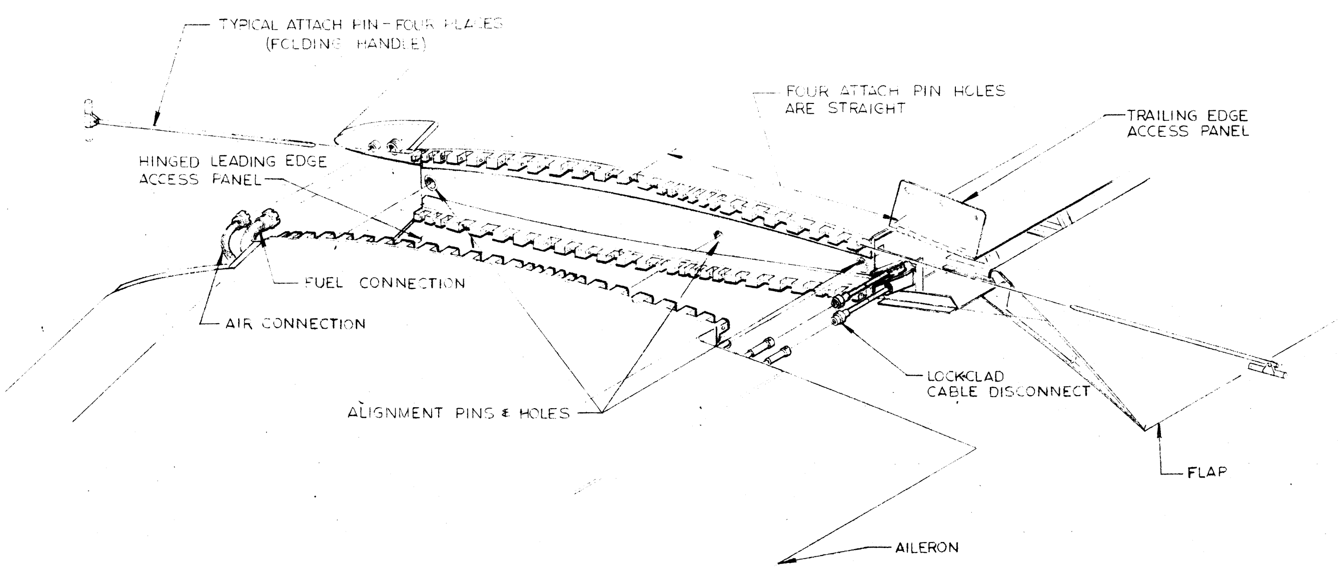
The use of detachable or folding wings for U-2 carrier operation leads to considering detachable outer wing panels. These detachable outer wing panels permit shortening the U-2 overall span by 30 feet for storage with a minimum expenditure of structural weight or loss of fuel.

The fuel loss offsets the structural weight change thus the total change made to the U-2 to provide detachable outer wings results in an addition of 8 pounds in weight and a loss of 7 gallons of fuel per side. The use of these panels is shown in Figures 12 and 13. Each panel weighs approximately 385 pounds and as such can be handled by four men. A fifth man is required to push home the four pins required to lock the wings in place.

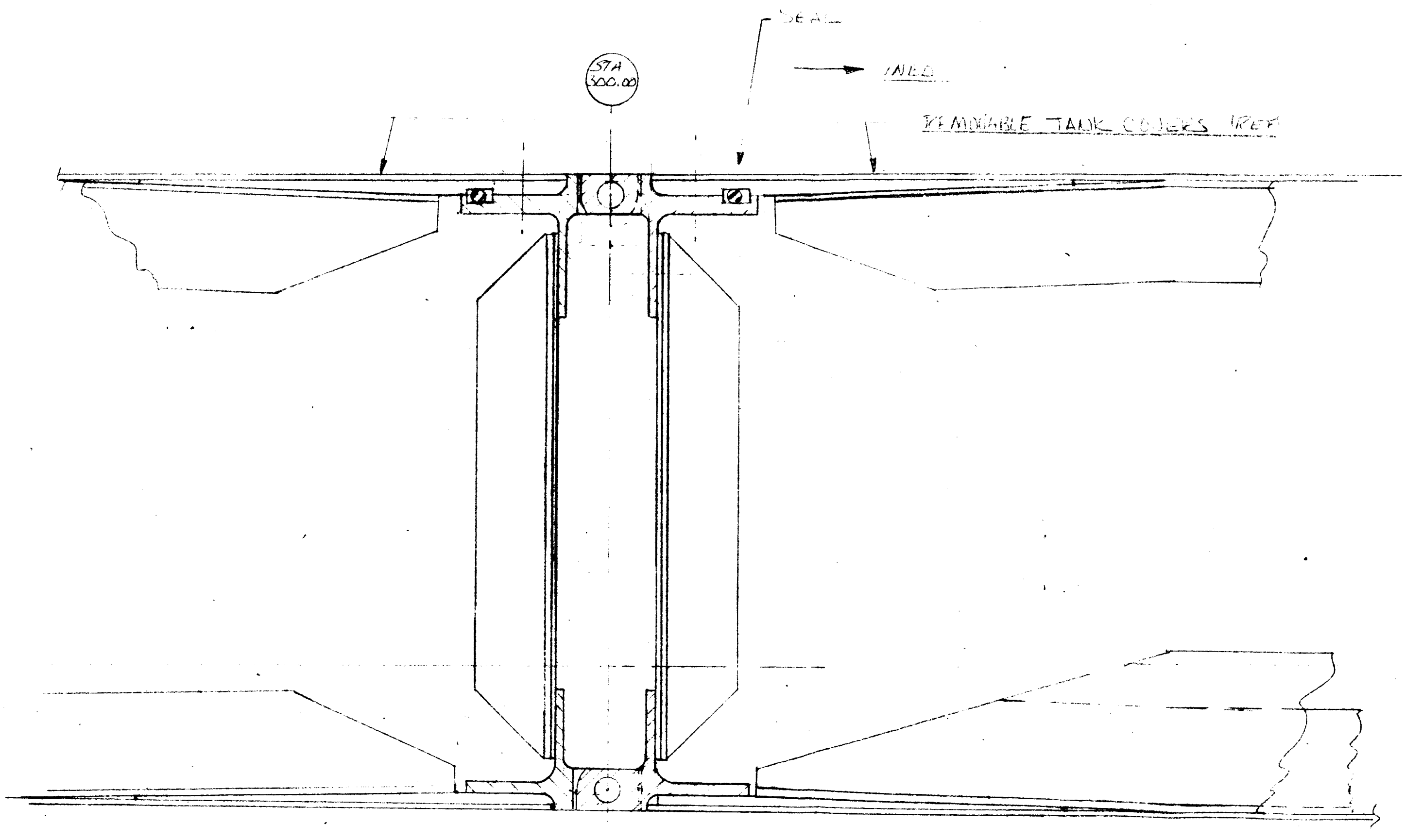
The type of wing joint illustrated in Figure 13 has been designed to minimize the added weight required to make the joint. This pin joint permits transferring the loads from skin to skin without having to gather the loads into concentrated points. The large hollow hinged pins are used to facilitate indexing when placing the outer wing in position for locking up.

Conventional Lock-Clad cable quick disconnects are used for the aileron control cables. These are to be spring loaded for ease of locking. Wiggins quick disconnects are used in the leading edge to provide fuel and air connections. The left wing only will have an electrical disconnect for the aileron tab operation.

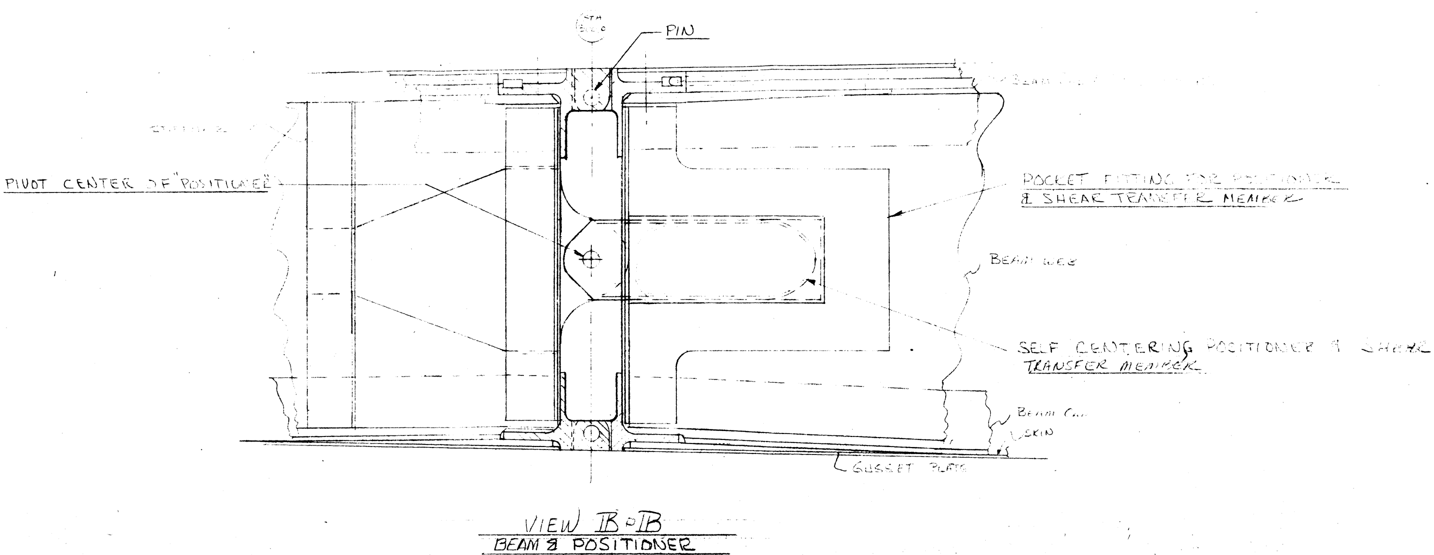
The structural provisions are shown in some detail in Figures 14, 15, 16 and 17. The above structural, plumbing and control provisions will weigh 53.5 pounds. As stated above, this is mostly offset by the small loss of fuel in the joint area.



OUTER WING PANEL JOINT

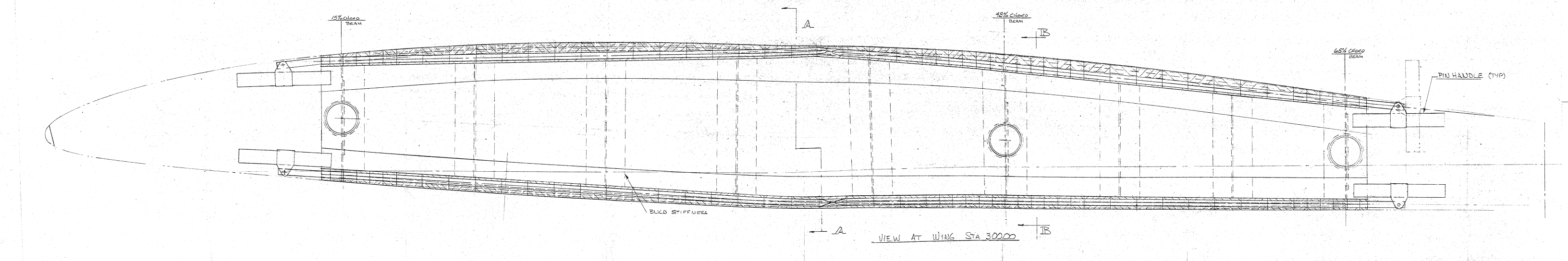


VIEW A-A

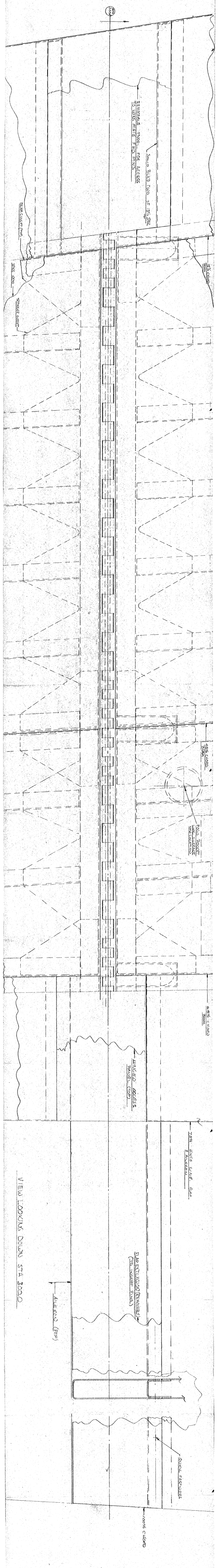


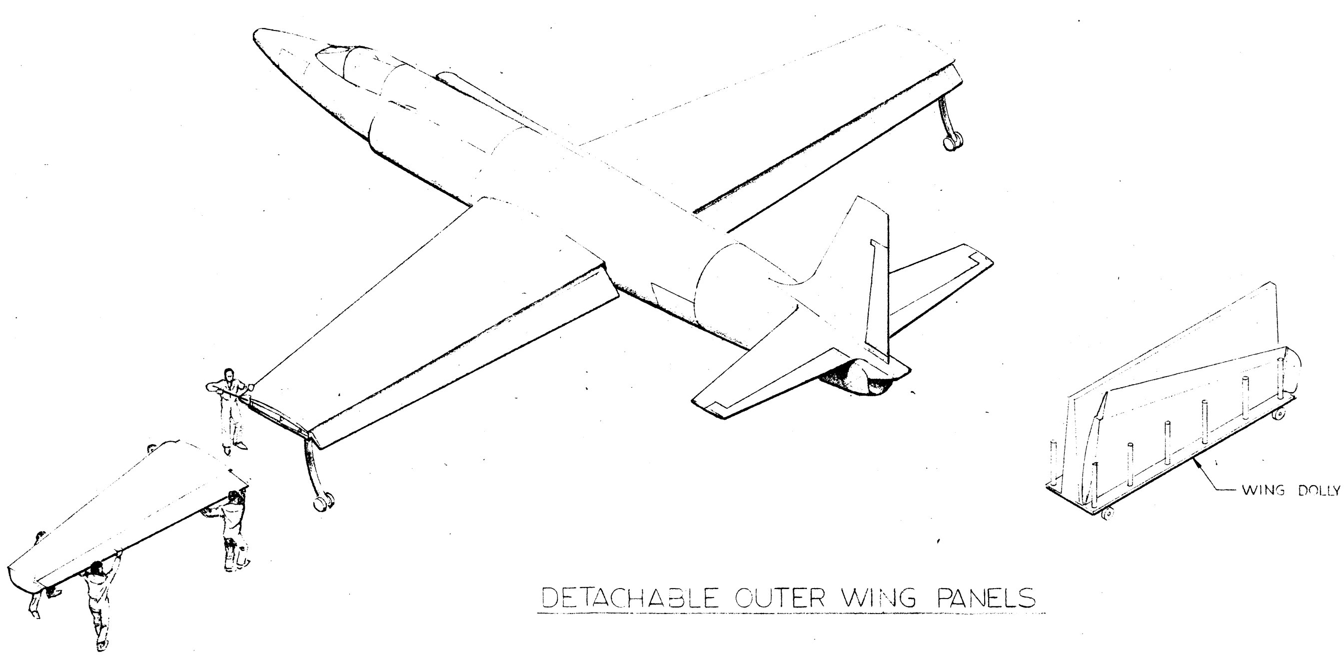
VIEW B-B
BEAM & POSITIONER

FIG. 15



VIEW AT WING STA 300.00


REMOVABLE PANEL FOR ACCESS TO WING MATE PIN
HINGED ACCESS PANEL (TOP)
AILERON (REF)
QUICK FASTENERS
VIEW LOOKING DOWN STA 3020



DETACHABLE OUTER WING PANELS

HIGH SINK RATES

The U-2 can be designed to take higher sink rates by the expedient of designing for higher load factors and larger stroke shock struts. The basic effects of these changes are in general to add weight to the overall aircraft structure.

Figure 18 graphically illustrates the different conditions of the structural weight increase imposed by the higher sink rates. Note that using the present landing gear geometry limits the sink rate to 12.5 feet per second at a load factor of 6.0.

A higher sink rate can be absorbed and still maintain a load factor of 6.0 by increasing the shock strut stroke. In fact, the full mil spec requirement of 20.8 feet per second can be met with a stroke of 18 inches which is mechanically feasible to design into the U-2.

The problem here is to limit the weight increase and still provide for reasonably high sink rates. Figure 18 indicates the whole range of sink rates and as such permits juggling the requirements to fit the U-2 tactics. It seems reasonable, considering the low wing loading and slow landing speeds of the U-2, to design to a slightly lower sink rate than that required for fighter types.

The present U-2 landing gear, designed for 6.0 feet per second rate has been giving excellent operational service indicating that this sink rate is correct for airport operations. Thus, if a rather

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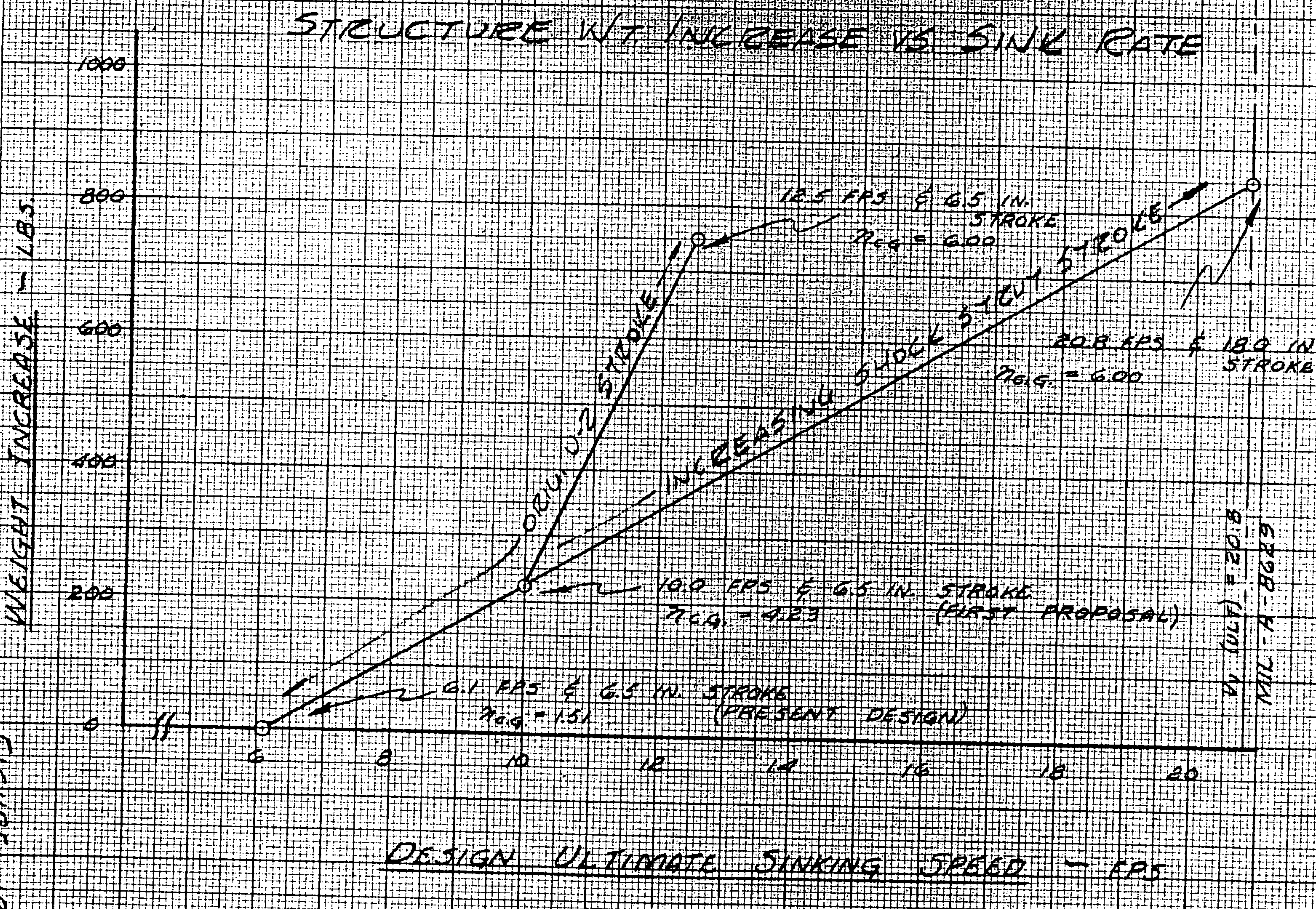


FIGURE 18

FORM 5278

large deck pitch rate of 10 feet per second is assumed, then the total sink rate imposed on the U-2 would be 15 to 16 feet per second. The result of designing to the criteria of 15 feet per second sink rate can be seen on Figure 18 to result in additional structural and mechanical weight of approximately 500 pounds.

If a higher sink rate is desired without the addition of a mechanism which would permit a longer stroke, the following table illustrates the rapid rise in load factors with increasing sink rates.

Sink Rate	Stroke	Load Factors n_{Gear}	$n_{C.G.}$
10 fps	6.5 inches	3.56	4.23
11		4.10	4.77
12		4.95	5.62
13		5.75	6.42
14		6.61	7.28

Since the fuselage presently is designed to an ultimate gust load factor of 6.0 g's, it would be undesirable to exceed this value. This would, therefore, limit the ultimate design sink rate to 12.5 fps. Redesign of the main landing gear, tail landing gear, fuselage attachment and support structure would be involved.

The addition of a shrinking mechanism to the main landing gear, to compress the strut when raising it into the wheel well to allow utilizing the maximum possible strut stroke, would permit higher sink rates as illustrated below.

Sink Rate	Stroke	Load Factors n_{Gear}	$n_{C.G.}$
20.8	16 inches	5.95	6.62
	17	5.62	6.27
	18	5.34	6.01
	19	5.07	5.74
	20	4.82	5.49

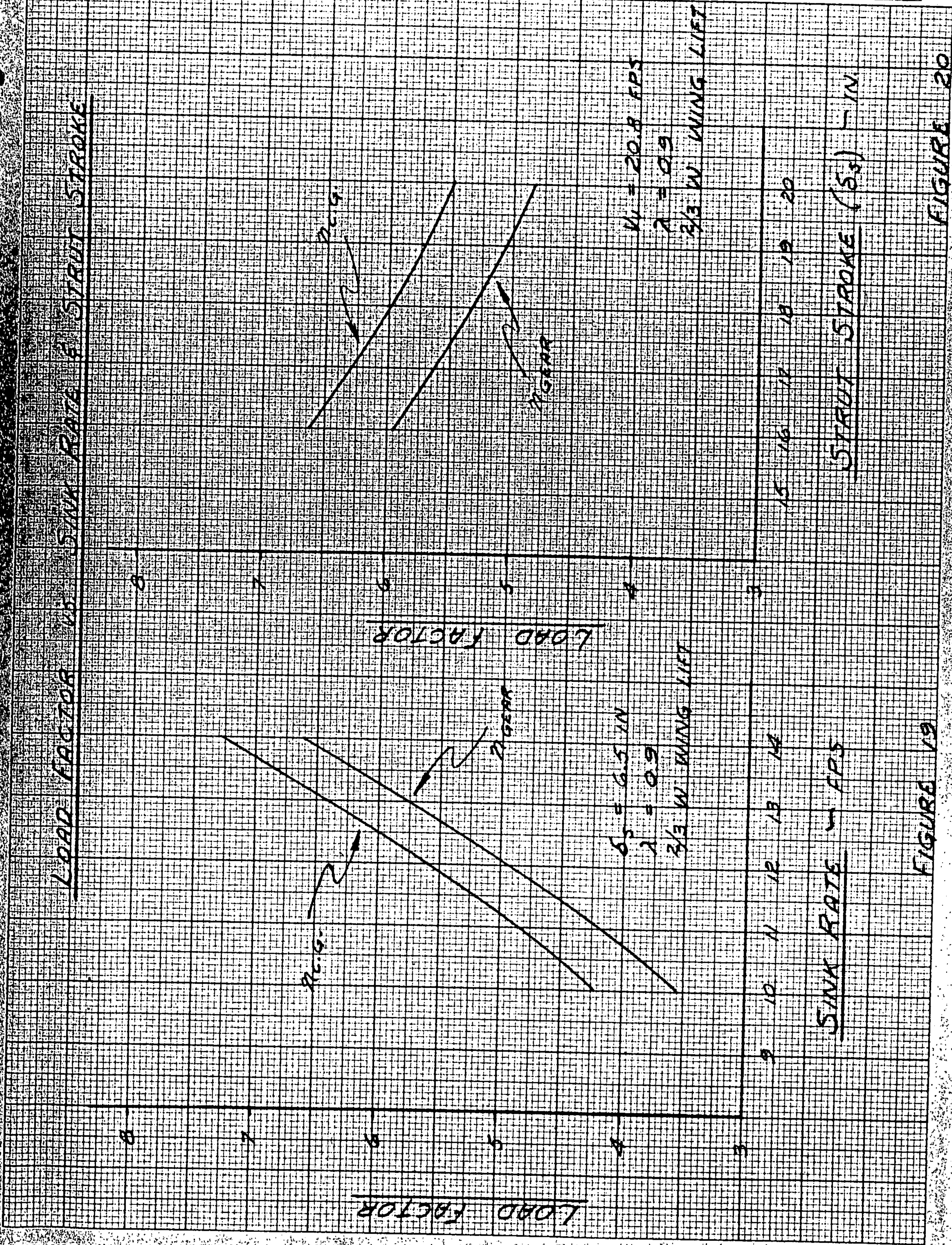
The two sets of data tabulated above are illustrated in Figures 19 and 20. The load factors for the gear and the C.G. are calculated in accordance with the mil spec.

Comparing the data and considering the operational tactics used by the U-2 it appears reasonable to design to the 15 feet per second sink rate which would cost 500 pounds as noted above.

DATE ____ GE ____

CHECKED BY ____ CALIFORNIA DIVISION MODEL ____

REPORT NO. ____



FORM 5276

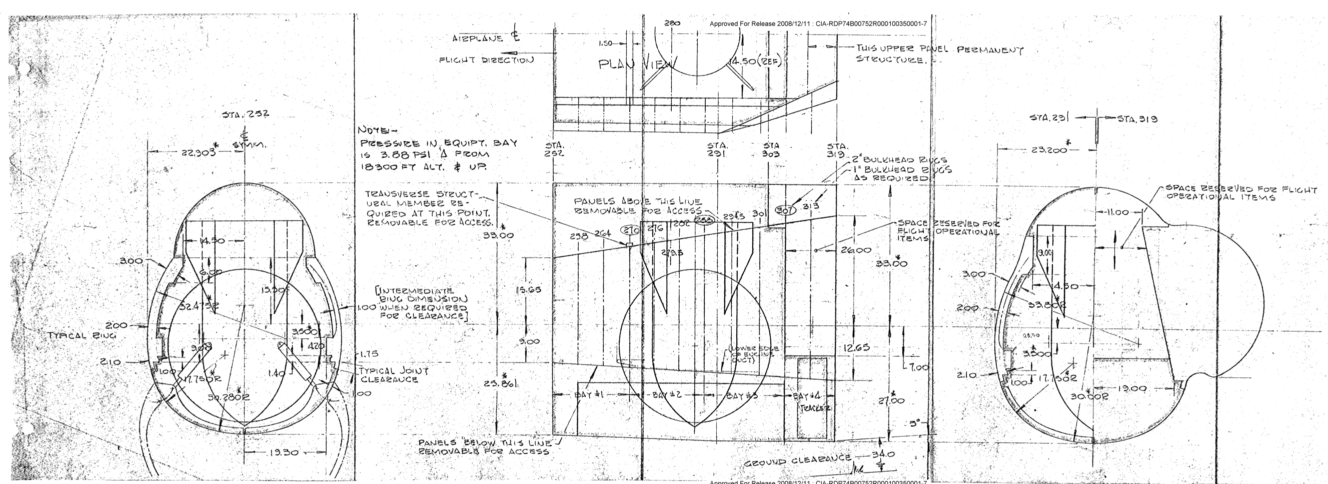
EQUIPMENT BAY LOADS

The size and accessibility of the equipment bay is shown in Figure 21. This permits the use of a great variety of tactical loads including Photo, ECM, Air Samplers, weather research, high resolution radar and infra-red. Most of the above packages have been fitted to the U-2. Each of the above tactical loads uses separate lower hatches to complete their installation.

The loads in the equipment bay can be as high as 1,000 lbs. and some of the above complete packages approach this weight within 30 pounds.

Illustrated in Figure 21 also are typical envelopes of disposable loads. The type of lower hatch illustrated for use with these loads has already been built for use with a downward ejection seat research program.

REPT. 12383



EQUIPMENT BAY CONFIGURATION.
SCALE - TENTH

NOTE -

1. THIS BAY IS TO CONTAIN ALL SPECIAL EQUIPMENT PLUS THE FOLLOWING REQUIRED FLIGHT OPERATIONAL ITEMS. SEE ATTACHED SHEETS FOR OUTLINES OF THESE ITEMS.
   1. BATTERY
   2. VOLTAGE REGULATOR
   3. TEMPERATURE CONTROL UNIT
   4. INVERTER 250 VA
   5. RECEIVER-TRANSMITTER
   6. COMPASS CONTROL S-3A
   7. COMPASS AMPLIFIER A-2
   8. JUNCTION BOX
   9. AMPLIFIER - INTERPHONE AIC-10
   10. REVERSE CURRENT RELAY AN3025-2
2. SPECIAL PAYLOAD EQUIPMENT TO BE LOCATED IN FOLLOWING SPECIFIED AREAS -
   CONFIGURATION A BAYS #1, 2 & 3
   CONFIGURATION B BAYS #1, 2 & 3
   CONFIGURATION C BAYS #1, 2 & 3
   C.C. EQUIPMENT BAY #4

* NOTE - REFER TO LOFT DATA FOR ACTUAL CONTOURS

FIGURE 21

4-9-55
REVISED 4-14-55